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REPORT NO T18/86

THE EFFECTS OF WEARING CHEMICAL PROTECTIVE CLOTHING ON COGNITIVE PROBLEM SOLVING

U S ARMY RESEARCH INSTITUTE
OF
ENVIRONMENTAL MEDICINE
Natick, Massachusetts

OCTOBER 1986

UNITED STATES ARMY
MEDICAL RESEARCH & DEVELOPMENT COMMAND

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AD-A176206

REPORT DOCUMENTATION PAGE

Form Approved
OMB No 0704-0188
Exp Date Jun 30, 1986

F SECURITY CLASSIFICATION ssified	1b. RESTRICTIVE MARKINGS
RITY CLASSIFICATION AUTHORITY	3. DISTRIBUTION/AVAILABILITY OF REPORT Approved for public release; distribution is unlimited.
LASSIFICATION/DOWNGRADING SCHEDULE	
FORMING ORGANIZATION REPORT NUMBER(S) 3/86	5. MONITORING ORGANIZATION REPORT NUMBER(S)
NAME OF PERFORMING ORGANIZATION S Army Research Institute of nvironmental Medicine	6b. OFFICE SYMBOL (If applicable) SGRD-UE-HP
7a. NAME OF MONITORING ORGANIZATION US Army Medical Research & Development Command	
ADDRESS (City, State, and ZIP Code) Natick, MA 01760-5007	7b. ADDRESS (City, State, and ZIP Code) Ft. Detrick, Frederick, MD 21701-5012
8a. NAME OF FUNDING/SPONSORING ORGANIZATION	8b. OFFICE SYMBOL (If applicable)
9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER	
8c. ADDRESS (City, State, and ZIP Code)	10. SOURCE OF FUNDING NUMBERS

PROGRAM ELEMENT NO.	PROJECT NO	TASK NO	WORK UNIT ACCESSION NO
6.3A	3M263764 D995	AF	DA 305220

11. TITLE (Include Security Classification)
The Effects of Wearing Chemical Protective Clothing on Cognitive Problem Solving

12. PERSONAL AUTHOR(S)
T. Michael Rauch, Calvin Witt and Louis Banderet

13a. TYPE OF REPORT	13b. TIME COVERED	14. DATE OF REPORT (Year, Month, Day)	15. PAGE COUNT
Technical Report	FROM _____ TO _____	October 1986	25

16. SUPPLEMENTARY NOTATION

17 COSATI CODES			18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number)
FIELD	GROUP	SUB-GROUP	Sustained Operations, Chemical Protective Clothing, Cognitive Performance, MOPP Gear, Circadian Rhythms. (& Microclimate Protective Postures)

19. ABSTRACT (Continue on reverse if necessary and identify by block number)

The present study investigated the effects of wearing various MOPP levels on three cognitive problem solving tasks over 24 hours of testing. The results show that wearing MOPP level 4 significantly impairs cognitive problem solving compared to MOPP 2 and a NO-MOPP control. The impairment attributed to the MOPP 4 condition was principally in the rate of task completion in contrast to task accuracy. The rate of task completion also varied significantly as a function of both temporal and nontemporal factors.

20. DISTRIBUTION/AVAILABILITY OF ABSTRACT	21. ABSTRACT SECURITY CLASSIFICATION
☒ UNCLASSIFIED/UNLIMITED ☐ SAME AS RPT ☐ DTIC USERS	Unclassified

22a. NAME OF RESPONSIBLE INDIVIDUAL	22b. TELEPHONE (Include Area Code)	22c. OFFICE SYMBOL
TERRY M. RAUCH, Ph.D., MAJ, MS	651-4855	SGRD-UE-HP

DD FORM 1473, 84 MAR 83 APR edition may be used until exhausted
All other editions are obsolete

SECURITY CLASSIFICATION OF THIS PAGE
UNCLASSIFIED

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TECHNICAL REPORT

NO. T18/86

THE EFFECTS OF WEARING CHEMICAL PROTECTIVE CLOTHING ON COGNITIVE PROBLEM SOLVING

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ABSTRACT

The present study investigated the effects of wearing various MOPP levels on three cognitive problem solving tasks over 24 hours of testing. The results show that wearing MOPP level 4 significantly impairs cognitive problem solving compared to MOPP 2 and a NO-MOPP control. The impairment attributed to the MOPP 4 condition was observed in the rate of task completion in contrast to task accuracy. The rate of task completion also varied significantly as a function of both temporal and nontemporal factors.

INTRODUCTION

Chemical protective (CP) clothing is designed as a means of defending against chemical hazards. U.S. Army personnel employ four Mission Oriented Protective Postures (MOPP) to achieve an appropriate level of individual protection from chemical agents on the battlefield (16). The MOPP system is characterized by four separate levels of protection which progressively achieve total encapsulation in MOPP level 4. Although MOPP provides varying degrees of physical protection, the relative impermeability of CP clothing may compromise thermal regulation, comfort, work efficiency and psychological functions. Most work to date on CP clothing has focused on physiological responses to thermal stress, while little research has addressed psychological (cognitive) variables affected by MOPP.

Previous studies have determined that wearing CP clothing in warm-hot environments impedes evaporative cooling and results in thermal strain and a diminished physical work capacity (5,6,7,8,10,13). In addition, it is well accepted that auxillary cooling methods are effective in heat removal while wearing MOPP 4 (18,19).

Few studies have adequately addressed the influence of MOPP on cognitive, perceptual and psychomotor performance. Fine and Kobrick (3) investigated the effects of wearing MOPP 4 in hot (91F., 61%RH) and normal (55F., 35%RH) conditions compared to a NO MOPP control (70F., 35%RH) over eight hours duration on sustained, sedentary military task performance. Their results showed that performance on cognitively based military tasks began to markedly degrade after four to five hours of exposure to the hot condition in MOPP 4. The MOPP 4 system by itself, however, (MOPP 4 at 55F., 35%RH) appeared to cause a decrement in performance at certain points in time, although, this effect was not consistently statistically significant. A serious limitation to detecting visual signals while wearing the MOPP 4 system was reported by Kobrick and Sleeper (12). This degradation in functional vision occurred early and remained throughout eight hours of testing. Johnson et al. (9) investigated the impact of wearing the CP mask and hood with rubber gloves on the soldier's ability to perform one-handed and two-handed tasks of manual dexterity. The results indicated that compared to bare handed conditions, manual dexterity was substantially poorer with the gloved hand. Moreover, the performance was unaffected by whether the soldier was wearing the mask with hood. A similiar study investigated the effects of wearing various combinations of the mask with hood and gloves on math computation using paper and pencil (17). The results coorborate the findings of Johnson et al (9), indicating that the poorest performance was observed in the gloved only and mask/glove conditions compared to no gloves/no mask and mask only conditions. Furthermore, the principal decrement was in the number of problems completed (i.e., speed) in contrast to the accuracy of answers. Although these studies impressively demonstrated specific MOPP related performance degradations occuring as a function of short term exposure, little systematic investigation has been directed toward the continued wear of MOPP beyond eight to ten hours. Current Army guidance suggests that MOPP gear may be worn for periods of 20 to 24 hours. A study on the effects of prolonged wear of MOPP levels and subsequent influences on cognitive performance is therefore indicated.

Numerous studies have investigated nontemporal factors and circadian influences on performance over 24 hours. It is well accepted that body temperature varies rhythmically over the day, with a difference of about 0.5C between peak and trough values. The minimum value occurs around 0400 hours and rises to peak around 2000 hours (2). Kleitman (11) and Colquhoun (2) have emphasized the strong parallelism between the circadian rhythms of temperature and performance. Performance on some tasks show a steep rise from early to mid-morning, a gradual rise to an evening peak, followed by a sharp decline into the sleeping hours. Monk (15) reported that tasks in which such a pattern is evident are visual scanning tasks in which the subject is working through visual material, finding and indicating targets. On the other hand, more complex tasks, involving high memory load, show a different time of day effect. Performance on an immediate memory task shows a decline over the waking day, with a trough in the early evening (4). Hence, previous studies of circadian rhythms in performance have demonstrated that there is no single circadian rhythm in performance efficiency. To some extent, the variation in performance measures would appear to be dependent on the inherent nature of the information processing demands of the specific task. Clearly there exists a need to systematically study nontemporal factors and the circadian variation of performance in specific types of cognitive tasks.

The purpose of the present study was to investigate the effects of wearing various MOPP levels on solving cognitive problems with paper and pencil over a 24 hour continuous operation. Inherent in performance over prolonged periods of time is the sensitivity of various types of cognitive tasks to time of day effects. Consequently, an additional purpose of this study was to determine the sensitivity of different cognitive tasks to time of day effects and potential interactions with MOPP levels.

METHOD

Subjects

The subjects consisted of nine male volunteers currently on active duty in the US Army. All subjects were medically screened prior to participation in the study, had normal visual acuity (20/20 Snellen), and were instructed to read and sign a volunteer agreement of informed consent. Subject ages ranged from 18 to 30 years.

Cognitive Tests

Three paper and pencil tests of cognitive performance were administered at scheduled times throughout each 24 hour period of testing. Math Computation (MA), Pattern Recognition (PR), and Number Comparison (NC) tests were administered on the average at 0900 hours (1st), 1300 hours (2nd), 1700 hours (3rd), 2200 hours (4th), 0030 hours (5th), 0500 hours (6th), and 0730 hours (7th). The three cognitive tests were adapted from the Performance Evaluation

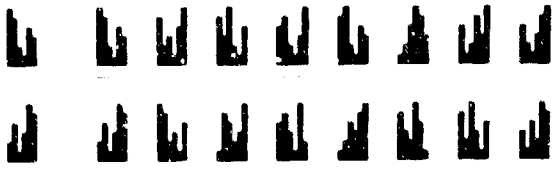
Tests for Environmental Research (PETER). MA required the addition of three 2-digit numbers arrayed vertically, is a measure of number facility, and a common attribute in many military tasks. PR required the recognition of a pattern (histogram) from among other histogram patterns and is similiar to a task of discriminating targets. A problem consisted of a sample pattern, followed by eight patterns one of which matches the sample for a correct response. NC problems required comparing two horizontally arranged 3-9 digit numbers, similiar to map grid coordinates, and selecting whether they are "same" or "different". Both PR and NC are measures of perceptual speed. All tests had alternate forms and a sufficient number of problems to preclude anyone from completing the test during a three minute test administration. Figure 1 shows a sample of problems from each test.

Figure 1. Cognitive Tests

ADDITION

71	20	27	53	20
19	51	83	33	35
76	40	47	67	11

PATTERN RECOGNITION



NUMBER COMPARISON

845793858 845793858

50237 20237

976 976

0623385 0623325

239055610 233055610

Apparatus and Equipment

The present investigation was part of a larger collaborative study with the Human Engineering Laboratory and Natick Research and Development Center. The overall purpose of the study was to operationally test a generic command post vehicle with associated developmental chemical protective clothing and life support equipment. The prototype items were developed by the Individual Protection Laboratory, and Food Engineering Laboratory, Natick Research and Development Center, and included the overgarment, gloves, boots, M25 A1 mask modified with food and drinking ports, an air-cooled vest, food and fluids. The command post vehicle was configured to support the operation of an artillery Fire Support Team (FIST).

Design and Procedure

Nine subjects were randomly assigned to three crews. Each crew (N = 3) participated in three, 24-hour periods of FIST operation in the command post vehicle. Each 24-hour period was conducted in one of three MOPP conditions; NO-MOPP (i.e., Battle Dress Uniform), MOPP 2 (overgarment worn unbuttoned and overboots), and MOPP 4 (overgarment worn buttoned, overboots, gloves, and mask worn). The MOPP 4 condition included a mask with a ventilated face piece, and eating and drinking ports in addition to an air-cooled vest. The MOPP 2 condition consisted of the same chemical protective ensemble except the vehicle supplied filtered, overpressured air to the crew compartment. The NO-MOPP condition was conducted with the vehicle supplying filtered, overpressured air to the crew compartment. All three crews were trained on the cognitive tests for one week prior to the start of the study with 12 trials occurring in the vehicle during MOPP 4, MOPP 2, and NO-MOPP conditions. The order of MOPP conditions was randomized. In each condition the crew performed FIST operations to include processing digital fire missions, entry and exit of the vehicle, light maintenance tasks, and cognitive testing at the scheduled times. Each cognitive test was administered for three minutes prior to which subjects were instructed to "work as quickly and as accurately as possible." The crews received three meals per 24 hour period. Consumption of food and fluids while wearing the mask during the MOPP 4 condition was achieved by the use of tube food units. The total calories per day per man for each MOPP level was similiar (NO MOPP = 2600 calories/man; MOPP 2 = 2900 calories/man; and MOPP 4 = 2850 calories/man). Each crew adjusted the temperature of the overpressured air in the crew compartment to a perceived level of thermal comfort in the NO-MOPP and MOPP 2 conditions while the MOPP 4 condition utilized air-cooled vests. The crew compartment temperature was always maintained $\leq$ 75 degrees F as measured by a Brantiff thermometer in the vehicle. All subjects were monitored for core body temperature by wearing a rectal probe thermistor.

RESULTS

Cognitive test scores were analyzed to reflect the percent of problems completed based on a three minute test administration and a total of 150 problems (i.e., speed of cognitive problem solving) and the percent of problems wrong (i.e., accuracy, computed from the number of problems wrong/number of problems completed). The means and standard deviations of the percent of problems completed and the percent of problems wrong for each of the three cognitive tasks by MOPP level and time of day are presented in Tables 1 and 2 respectively. Mean values for core body temperature and dry bulb crew compartment temperature by MOPP level and time of day are depicted in Table 3. A 3 X 7 repeated measures analysis of variance (within factors were MOPP level and time of day) on the percent of problems completed and the percent of problems wrong revealed a significant main effect of the MOPP condition for %MA completed, $F(2,16) = 6.22$, $p < .01$, %PR completed, $F(2,16) = 10.82$, $p < .001$ and %NC completed $F(2,16) = 9.12$, $p < .002$. It should be noted that no significant differences in core body temperature existed among MOPP levels presumably due to the use of cooling vests during MOPP 4 and the ability of crewmen to adjust compartment cooling in the NO-MOPP and MOPP 2 conditions. As expected, there were significant differences in the self-adjusted crew compartment temperatures among MOPP levels, $F(2,16) = 22.23$, $p < .001$.

A significant main effect was found for time of day on %MA completed, $F(6,48) = 7.08$, $p < .001$, %PR completed, $F(6,48) = 6.19$, $p < .001$, %NC completed, $F(6,48) = 4.59$, $p < .001$, core body temperature, $F(6,48) = 40.42$, $p < .001$ and crew compartment temperature, $F(6,48) = 6.02$, $p < .01$. There was a significant interaction effect for crew compartment temperature by MOPP level by time of day, $F(12,96) = 7.49$, $p < .001$. The least variation in self-adjusted crew compartment temperature was seen in the MOPP 4 condition over 24 hours. On the other hand, large differences in crew compartment temperature occurred for both the NO-MOPP and MOPP 2 conditions with the lowest compartment temperatures recorded after 2200 hours.

A Scheffe test ($p < .05$) was performed for posteriori contrasts on all significant main effects which did not have a significant interaction. The results showed that MOPP 4 performance was significantly degraded for %MA, %NC and %PR problems completed when contrasted with NO MOPP and MOPP 2 performance. There were no significant differences between the MOPP 2 and NO MOPP groups on the percent of cognitive problems completed.

Figures 2-4 depict the mean percent of problems completed on each of the three cognitive tasks as a function of time of day and MOPP level. Clearly, the MOPP 4 condition shows the most profound decrement while time of day effects were significant for %MA, %PR and %NC problems completed. Figure 5 shows core body temperature changes as a function of MOPP level and time of day.

DISCUSSION

The results of the present study show that MOPP 4 significantly degrades cognitive problem solving compared to MOPP 2 and NO-MOPP conditions. Since there was no significant variation in core body temperature among MOPP levels, fundamental differences may be attributed to the human factor encumbrances (i.e., limitations of mobility and sensory-perceptual capabilities) of MOPP items and not confounded by thermal stress. It is worthy of note that the primary effect of MOPP 4 on cognitive problem solving is in the speed or rate of task completion. The slower rate of cognitive problem solving in the MOPP 4 group is presumably associated with wearing the CP mask and gloves. In MOPP 4, wearing both the CP mask and gloves suggests that performance could be impaired by input (i.e., visual distortions) and/or output (i.e., manual dexterity) factors. In a recent study, Johnson et al. (9) found that compared to bare handed conditions, fine finger manual dexterity was substantially poorer in a group wearing the CP glove. Moreover, the performance between bare handed and gloved conditions remained the same regardless of wearing the CP mask with hood. Rauch (17) reported that wearing CP gloves only or wearing both the mask and gloves significantly influenced cognitive problem solving (math computation with paper and pencil) compared to no mask/no gloves and no gloves/mask conditions. Wearing the mask only did not produce significant performance decrements. Furthermore, the performance decrement was observed in the speed of math problem completion and apparently due to the greater amount of time required to write three digit answers using paper and pencil while wearing the gloves. Therefore the rate of performing math computation, using paper and pencil, was most sensitive to the encumbrance of wearing gloves and writing 3 digit sums. It is problematic to generalize the glove effect to NC and PR completion rates since both require less time and less manual dexterity in writing the answers; single letters indicating same "S", or different "D" for each NC problem and an "X" for each PR problem.

Cognitive problem solving varied over the 24 hour period of testing. Differences among the time of day performances revealed significant impairment on the rate of task completion in contrast to accuracy for MA, NC and PR tasks. These findings support previous research indicating that speed and accuracy are often differentially affected (1,2). Since the three cognitive tasks were self-paced, it is not unreasonable to conclude that subjects engaged in a typical cognitive strategy of compromising speed to maintain accuracy over time. The slowest rate of performance was found at 0500 hours compared to other times over the 24 hour period. This study also represents the first effort to show the temporal sensitivity of MA, PR and NC sub-tests of the PETER battery.

The variability in cognitive rates of performance among MOPP levels and time of day may be a function of the type of visual information presented. With NC tasks very little information is presented and abstracted from a single eye fixation compared to pattern contours in PR and vertical addition in MA. Differences in the visual display of stimulus information could explain the greater number of problems completed for NC tasks since presumably less time is spent on each problem compared to MA and PR. The smaller amount of information present in NC tasks requires less processing time, and therefore more problems are completed.

Core body temperatures varied in accord with the typical circadian rhythm, demonstrating a low at 0500 hours and a high in the late afternoon at 1700 hours. The elevated core temperatures noted at 0900 hours, near the start of the test for each condition, is believed to be a function of the increased activity and arousal of starting the experiment. The circadian variation of core temperature appears not to have been differentially affected by any of the MOPP levels. Clearly, the present findings show the slowest performance on all three cognitive tasks occurred between 0030 and 0500 hours which also corresponds to the lowest core body temperature.

The rate of cognitive problem solving was probably also influenced by nontemporal factors. Performance trends for all three tasks show two production curve characteristics; namely: (1) an end-spurt effect and (2) fatigue effects (14). The lack of a warm-up effect may have been obscured by heightened arousal at the start of the study.

The results of the present study have serious implications regarding military performance while wearing MOPP gear. Threat doctrine will employ persistent agents in rear areas to disrupt combat service support. The speed of performing tasks of short duration (i.e., 3 minutes) which require manual dexterity can expect to be severly degraded while wearing the NBC gloves. Hence, many of the routine tasks of a maintenance battalion, supply and transport battalion, or division material management center may require a significantly longer time to complete accurately while wearing the CP mask and gloves. Future MOPP research should investigate tasks of longer duration (i.e., 30, 45, and 60 minute tasks) relative to the speed and accuracy of completion.

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TABLE 1. COGNITIVE PERFORMANCE BY MOPP LEVEL BY TIME OF DAY

	PERCENT COMPUTATION ATTEMPTED/MINUTE		PERCENT PATTERN RECOGNITION ATTEMPTED/MINUTE		PERCENT NUMBER COMPARISON ATTEMPTED/MINUTE	
	Mean	Standard Deviation	Mean	Standard Deviation	Mean	Standard Deviation
MOPP LEVEL						
0						
TIME OF DAY						
0800 HOURS	21.78	4.33	29.58	4.57	47.11	8.34
1300 HOURS	22.96	6.92	28.74	5.37	47.04	10.94
1700 HOURS	23.19	4.09	30.52	4.36	52.15	14.66
2200 HOURS	20.00	5.04	30.07	6.68	47.41	17.13
0030 HOURS	20.07	5.14	25.63	7.01	43.41	6.64
0500 HOURS	19.63	3.25	28.52	4.58	42.74	9.58
0730 HOURS	23.58	3.47	33.89	5.73	50.58	18.13
2						
TIME OF DAY						
0800 HOURS	23.78	5.09	30.89	4.57	48.74	12.35
1300 HOURS	23.48	5.08	29.28	5.84	44.96	12.91
1700 HOURS	21.93	5.42	30.67	5.65	48.52	11.00
2200 HOURS	21.48	6.20	29.63	6.58	45.93	11.05
0030 HOURS	20.59	5.84	28.81	6.38	45.70	8.95
0500 HOURS	19.33	8.60	23.41	5.64	38.59	10.35
0730 HOURS	19.04	8.11	26.74	6.61	42.59	14.18
4						
TIME OF DAY						
0800 HOURS	21.26	4.59	28.07	7.05	44.30	10.30
1300 HOURS	20.74	4.65	26.67	6.94	39.33	7.72
1700 HOURS	20.37	6.85	27.11	7.11	43.33	14.48
2200 HOURS	18.07	5.54	25.41	5.24	36.59	10.26
0030 HOURS	17.93	8.56	23.26	7.78	42.37	17.51
0500 HOURS	15.04	6.65	20.52	7.81	29.19	11.86
0730 HOURS	18.44	8.08	26.22	7.38	38.56	12.53

TABLE 2. COGNITIVE PERFORMANCE BY MOPP LEVEL BY TIME OF DAY

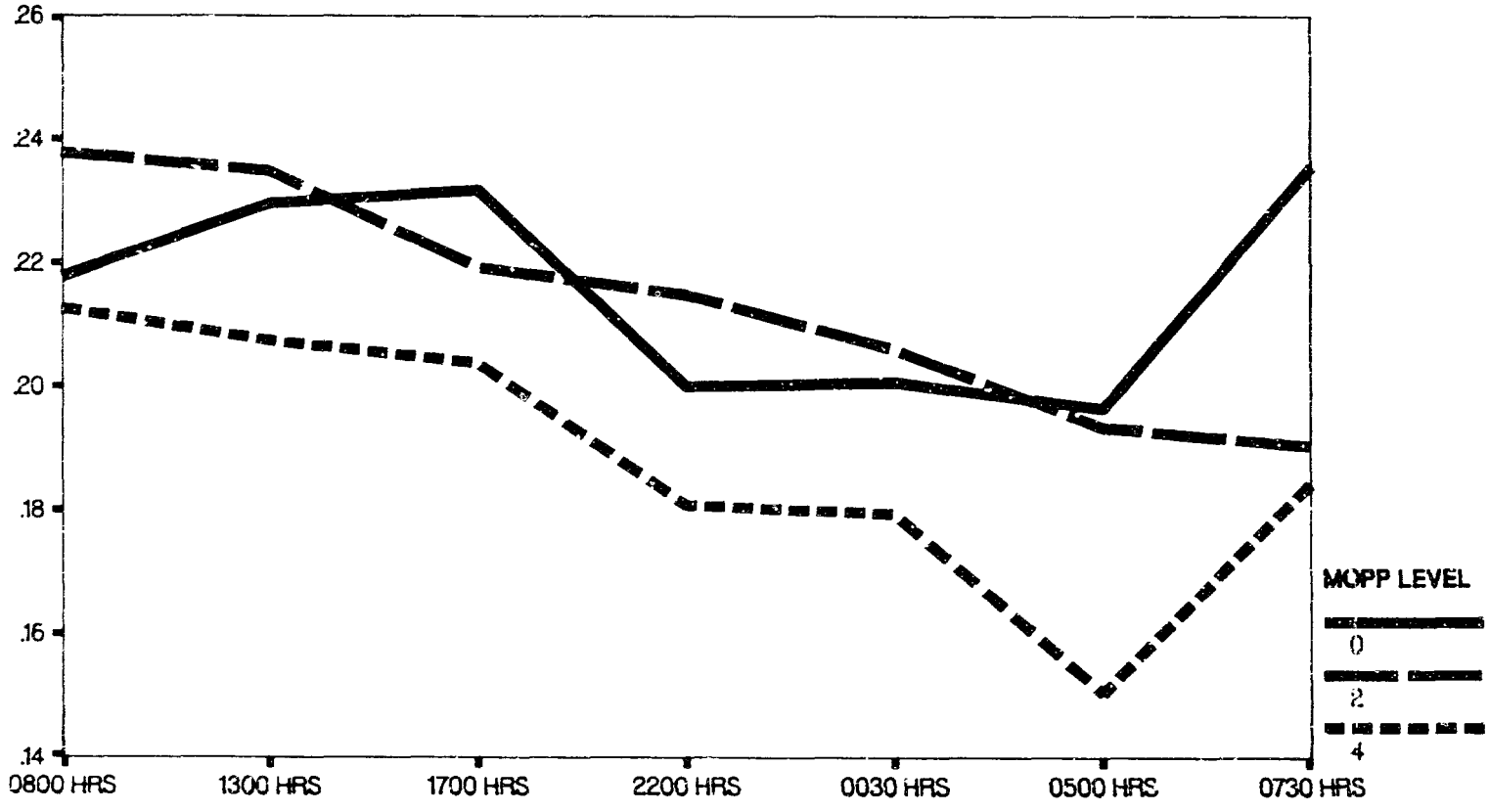
	PERCENT COMPUTATION ERROR/MINUTE		PERCENT PATTERN RECOGNITION ERROR/MINUTE		PERCENT NUMBER COMPARISON ERROR/MINUTE	
	Mean	Standard Deviation	Mean	Standard Deviation	Mean	Standard Deviation
MOPP LEVEL						
0						
TIME OF DAY						
0800 HOURS	5.10	4.20	3.37	2.06	2.34	2.12
1300 HOURS	3.70	2.86	2.19	2.28	3.57	3.05
1700 HOURS	2.12	2.91	.97	1.18	4.72	3.62
2200 HOURS	3.18	2.78	3.29	3.10	4.29	3.44
0030 HOURS	7.76	7.06	2.20	3.39	4.56	3.20
0500 HOURS	3.69	6.34	1.82	2.19	4.44	4.37
0730 HOURS	3.99	3.54	4.98	3.40	5.05	2.90
2						
TIME OF DAY						
0800 HOURS	4.74	4.64	1.96	2.90	4.29	2.02
1300 HOURS	4.10	4.46	5.00	4.79	3.46	3.33
1700 HOURS	3.99	3.59	2.20	2.50	3.63	2.32
2200 HOURS	1.21	1.99	3.57	3.05	3.25	2.35
0030 HOURS	2.09	2.82	2.84	5.50	5.26	3.70
0500 HOURS	3.41	3.89	3.38	3.45	4.81	5.26
0730 HOURS	2.47	2.83	2.59	4.00	5.79	3.50
4						
TIME OF DAY						
0800 HOURS	4.39	6.70	2.58	2.92	5.91	4.02
1300 HOURS	2.69	2.16	3.98	4.08	4.72	4.64
1700 HOURS	4.09	5.34	3.62	3.92	5.45	3.66
2200 HOURS	2.43	3.57	3.12	3.39	7.63	8.10
0030 HOURS	8.55	13.03	2.80	3.18	8.26	9.18
0500 HOURS	6.82	7.26	5.93	6.38	5.10	6.38
0730 HOURS	4.40	3.84	1.09	1.21	8.68	13.58

TABLE 3 CORE BODY TEMPERATURE AND DRY BULB CREW COMPARTMENT TEMPERATURE BY MOPP LEVEL BY TIME OF DAY

	CORE BODY TEMPERATURE (C)	DRY BULB TEMPERATURE (C)
	Mean	Mean
MOPP		
0		
TIME OF DAY		
0300 HOURS	37.36	19.88
1300 HOURS	37.03	23.71
1700 HOURS	37.43	23.52
2200 HOURS	37.09	17.78
0030 HOURS	36.71	21.28
0500 HOURS	36.46	22.29
0730 HOURS	36.43	23.52
2		
TIME OF DAY		
0800 HOURS	37.30	23.24
1300 HOURS	37.24	24.54
1700 HOURS	37.73	27.44
2200 HOURS	37.10	22.96
0030 HOURS	36.76	20.35
0500 HOURS	36.46	19.51
0730 HOURS	36.71	20.26
4		
TIME OF DAY		
0300 HOURS	37.55	19.04
1300 HOURS	37.16	18.48
1700 HOURS	37.20	17.36
2200 HOURS	36.82	21.65
0030 HOURS	36.31	21.84
0500 HOURS	36.55	18.62
0730 HOURS	36.49	21.28

FIGURE 2. PERCENT OF MATH COMPUTATION COMPLETED BY MOPP LEVEL BY TIME OF DAY

24 HOUR CONTINUOUS OPERATION



MEAN OF % MATH COMPUTATION COMPLETED

TIME OF DAY

FIGURE 3. PERCENT OF PATTERN RECOGNITION COMPLETED BY MOPP LEVEL BY TIME OF DAY

24 HOUR CONTINUOUS OPERATION

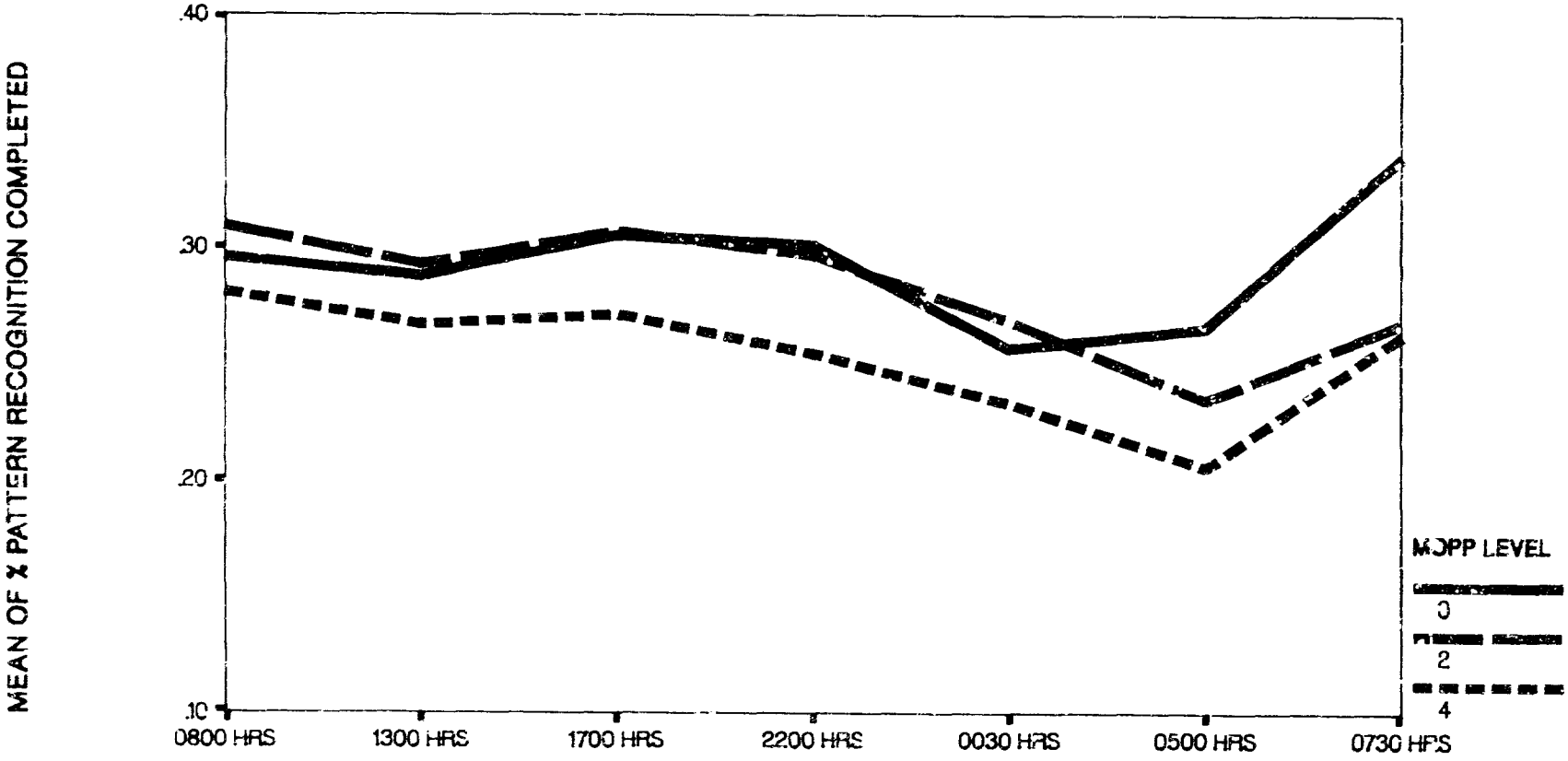


FIGURE 4. PERCENT OF NUMBER COMPARISON COMPLETED BY MOPP LEVEL BY TIME OF DAY

24 HOUR CONTINUOUS OPERATION

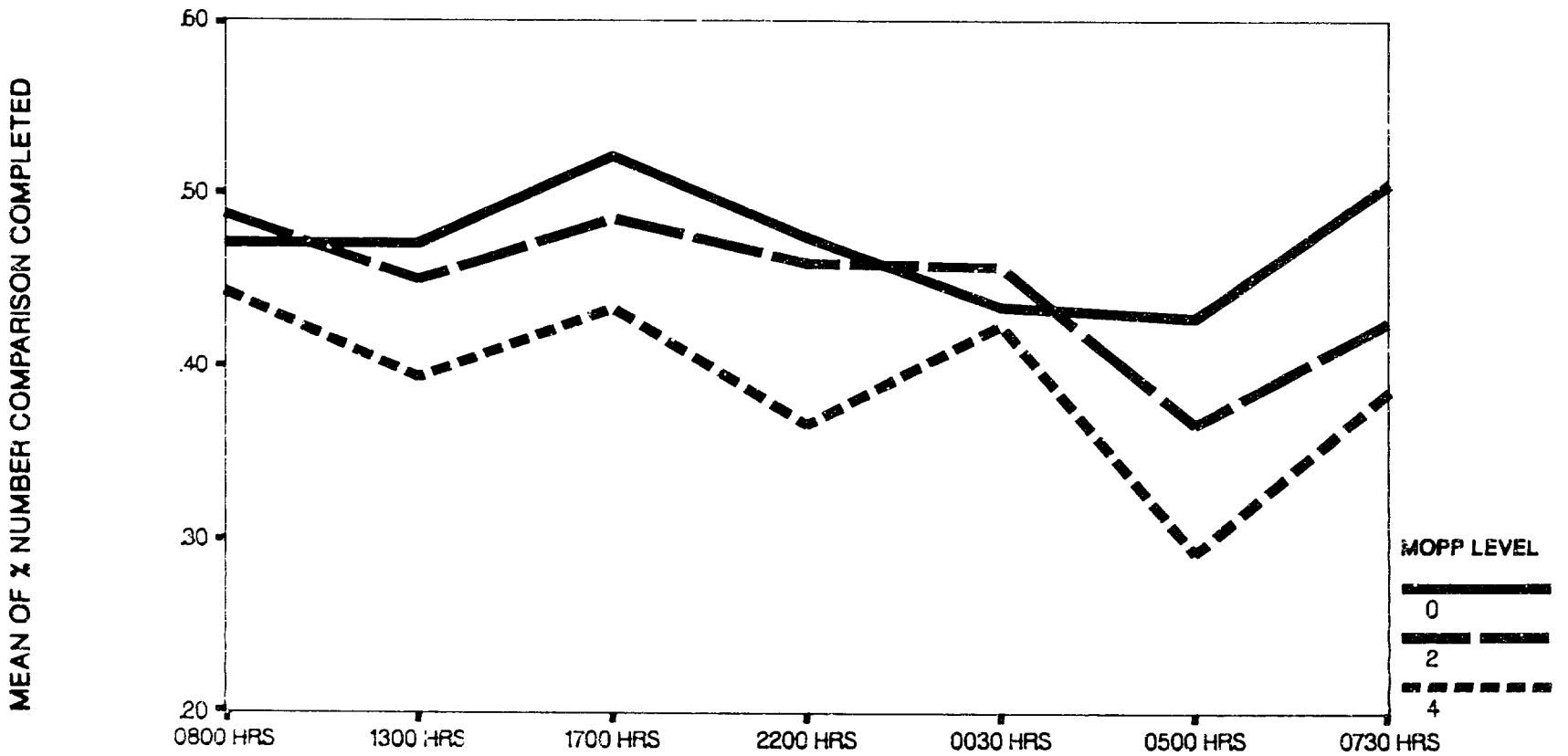
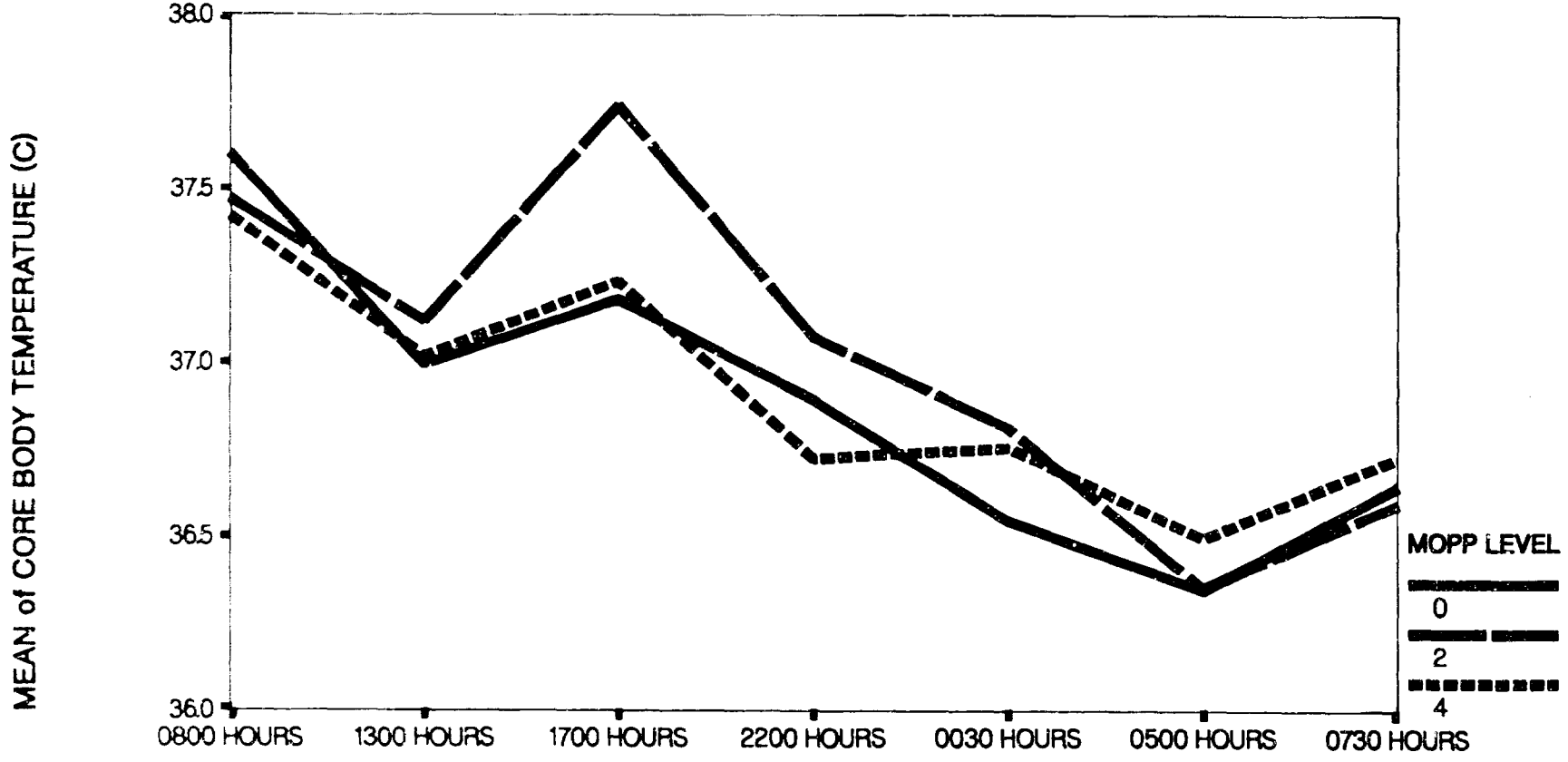


FIGURE 5. CORE BODY TEMPERATURE BY MOPP LEVEL BY TIME OF DAY

24 HOUR CONTINUOUS OPERATION



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